

[0001] The present invention relates to an axial piston machine, in particular, an air-conditioner compressor for motor vehicles, including at least one piston having a substantially cylindrical piston body and a brace that embraces a tilting ring or a tilting plate and piston shoes sliding on said tilting ring or said tilting plate; the brace having spherical cap-shaped depressions for receiving the piston shoes, said depressions being located on the side of the piston body and on the opposite side.

[0002] Axial piston engines of this kind are generally known. These axial piston engines have the disadvantage of requiring special machines or special devices for machining the spherical shape of the spherical cap-shaped depressions in the brace of the piston. The machining is carried out under interrupted cutting conditions, that is, the cutting tool moves out of and back into the workpiece during machining. Moreover, with the known machining methods, it is not possible to provide the edges of the spherical shape with lubricating wedge chamfers in a cost-effective manner. In the known machining processes, the spherical shape in the brace is machined with the cylinder axis of the piston in a fixed chucking position. In this connection, it is possible, inter alia, to produce the spherical shape by rotating the piston about an axis extending perpendicular to its cylinder axis and through the center of the sphere during the machining of the spherical form. However, these methods are cumbersome and error-prone and, as mentioned earlier, require special machines or special devices.

[0003] Also, the piston braces of known pistons project radially outward relatively far from the piston axis so as to provide sufficient space for the movement of the tilting plate or tilting ring and the piston shoes, while being sufficiently stiff to prevent the piston shoes from falling out.

[0004] Moreover, in tilting-ring or tilting-plate type compressors, the lubrication of the radially outward sliding surface of the brace between the piston and the housing is of great importance, especially if, when using CO₂ as the refrigerant, the machine dimensions are smaller than in conventional refrigerant compressors because of the high pressures. As a consequence of the tight spaces in a CO₂ compressor, the spaces between the pistons where lubricant can be distributed, for example, in the drive chamber, become narrower and narrower. The larger the peripheral housing region covered by the piston brace is compared

to the exposed peripheral region of the housing, the more difficult is it to supply lubricant to this region. If in tilting plate machines or tilting ring machines of this type, such as for CO₂ applications, the degree of coverage by the piston brace becomes relatively high so that there are only small gaps between the individual piston brace regions for introducing lubricant between the peripheral regions, insufficient lubricant supply and friction damage may occur in this area.

[0005] It is, therefore, the object of the present invention to devise an axial piston machine which will overcome these disadvantages.

[0006] This objective is achieved firstly by an axial piston machine, in particular, an air-conditioner compressor for motor vehicles, including at least one piston having a substantially cylindrical piston body and a brace that embraces a tilting ring or a tilting plate and piston shoes sliding on said tilting ring or on said tilting plate; the brace having spherical cap-shaped depressions for receiving the piston shoes, said depressions being located on the side of the piston body and on the opposite side; and the brace having an opening in its side opposite the piston body. A preferred axial piston machine is one in which the axis of the opening coincides with the axis of the piston body.

[0007] Also preferred is an axial piston machine, in which the opening is substantially cylindrical. Another preferred axial piston machine is one in which a tool for machining the spherical cap-shaped depressions in the brace can be introduced through the opening. An axial piston machine according to the present invention is characterized in that the machining motion for producing the spherical shape of the spherical cap-shaped depressions can be produced by rotating the piston about the axis of the piston body, that is, about the cylinder axis. This allows the spherical cap shapes to be produced by turning on standard lathes.

[0008] Another axial piston machine according to the present invention may have a centering hole or a centering center or a weight-reduction hole disposed on the piston body side of the brace opposite the brace side provided with the opening. Preferred is a piston in which a coating of the piston can be machined on lathes and grinding machines in a very stable chucking position by using the centering center.

[0009] A further preferred axial piston machine is one in which the spherical cap-shaped depressions can be produced using reversible inserts having a ready-made spherical contour.

[0010] Also preferred is an axial piston machine in which the piston can be manufactured as a single, solid piece from an aluminum material.

[0011] An axial piston machine according to the present invention is characterized in that a first spherical recess is disposed within the bridge of the brace, that is, in the inner radial region of the piston brace. A preferred axial piston machine is one in which the first spherical recess can be produced by rotating the piston about its cylinder axis with the tool rotating during the machining of the spherical shape in the brace.

[0012] In another axial piston machine according to the present invention, the first spherical recess can be produced by rotating the piston about an axis extending perpendicular to its cylinder axis without the tool rotating during the machining of the spherical shape in the brace.

[0013] Moreover, the spherical running surfaces of the piston shoes in the brace can seamlessly merge into the first spherical recess in the bridge of the brace, and the spherical running surfaces and the first spherical recess can preferably have equal sphere radii. Also preferred is a first spherical recess which can be processed by and during the machining of the piston shoe bearing surfaces, or fully produced by this machining process. Preferably, the bridge of the brace is adapted, on its inner side, to the contour of the tilting ring or tilting plate by a second spherical recess of larger radius outside the first spherical recess. In accordance with the present invention, the second spherical recess allows the bridge of the brace to be shifted as close as possible to the tilting ring or tilting plate. This reduces the bending load on the brace by shorter lever arms. The first spherical recess only slightly reduces the stiffness of the brace, because the first spherical recess is located very close to the bending line. This is made possible because the second spherical recess shifts the bending line of the brace so close to the tilting plate or tilting ring that the stiffness against bending during the suction movement is only slightly reduced compared to a brace without a first spherical recess. Because of this, less material and installation space are needed, which reduces costs.

[0014] It is a feature of an axial piston machine according to the present invention that the cylindrical piston body and the brace are two separate parts from which the piston can be assembled. The advantage of this is that the materials and manufacturing methods for these differently shaped parts can be adapted to the different loads.

[0015] Also preferred is an axial piston machine whose brace can be made from a strip of sheet metal and, after suitably shaping the metal strip, is connectable to the cylindrical piston body, which can be made as a deep-drawn part of sheet metal. Another preferred axial piston machine is one in which the opening in the brace can be made by punching. Also, the seating of the piston shoes can be produced or largely preformed during the forming process of the brace. Also preferred is an axial piston machine in which the cylindrical piston body and the brace can be made from a steel material. A further preferred axial piston machine is one in which the brace and the cylindrical piston body can be joined together by laser welding or resistance welding. Moreover, the hollow space between the brace and the piston body can be airtight, or nearly airtight.

[0016] Another embodiment of the axial piston machine according to the present invention is characterized in that, after the brace and the piston body are assembled together, the piston is first provided with an adhesive base coat, for example by phosphating, in a layer thickness of about 2-3 μm , and then provided with a surface coating of PTFE in a layer thickness of about 10 μm .

[0017] The objective is also achieved by an axial piston machine in which the outer side, as a sliding surface, of the brace has at least one opening to the inner radial region of the brace which faces the tilting plate or tilting ring. Preferably, the at least one opening serves to supply lubricant to the sliding surface, because the sliding surface is located in the peripheral region covered by the piston brace and, therefore, can only with difficulty be supplied with the lubricant contained in the refrigerant in the drive mechanism housing.

[0018] In a further embodiment of the axial piston machine according to the present invention, the peripheral region of the piston brace which is designed as a sliding surface has several and/or differently shaped openings or opening regions.

[0019] A preferred axial piston machine is one in which the peripheral region of the piston brace which is designed as a sliding surface has formed therein pocket-shaped regions opposite the drive mechanism housing wall which serves as a running surface, said pocket-shaped regions being supplied via at least one lubrication opening.

[0020] The above-mentioned embodiments allow the peripheral region covered by the piston brace to be supplied with lubricant that is spun off of the rotating tilting plate or tilting ring by centrifugal forces and thus enters the space between the piston and the housing wall through the openings.

[0021] The present invention will now be described with reference to the figures, in which:

[0022] Figure 1 is a cross-sectional view of a two-part piston;

[0023] Figure 2 shows the same piston in a side view;

[0024] Figure 3 shows the same piston in a perspective view;

[0025] Figure 4 illustrates the machining of the rear spherical cap;

[0026] Figure 5 illustrates the machining of the front spherical cap;

[0027] Figure 6 is a top view of a piston;

[0028] Figure 7 shows a piston with a first spherical recess;

[0029] Figure 8 illustrates the pressures determining the axial forces on the piston;

[0030] Figure 9 shows four representations of the first and second spherical recesses;

[0031] Figure 10 illustrates the production of the first spherical recess;

[0032] Figure 11 shows a piston in a portion of a tilting ring machine;

[0033] Figure 12 is a cross-sectional view through a piston brace;

[0034] Figure 13 is a top view of a piston;

[0035] Figure 14 shows the piston arrangement in the drive mechanism chamber;

[0036] Figure 15 shows a rotating tilting plate with a piston according to the present invention;

[0037] Figure 16 shows a piston having a lubricant pocket.

[0038] Figure 1 is a cross-sectional view of a two-part piston 1, which is composed of a cylindrical piston body 3 and a U-shaped piston brace 5. The two parts are joined together in region 7 by laser welding. However, other joining techniques, such as resistance welding, brazing, adhesive bonding, press-fitting, crimping, or form-locking connections, such as

circlips, threads, etc., are possible as well. Cylindrical piston body 3 can preferably be made from thin sheet steel using a deep drawing process. The use of steel sheet has the advantage that the piston body can have a thin-walled design in spite of high pressure loads, and that it can advantageously be produced in large quantities by deep drawing. However, the blanks of the parts can also be produced by cold extrusion, hot extrusion, or forging. In some cases, it can be advantageous to manufacture such a piston from aluminum materials. Piston brace 5 can be made from a strip of sheet steel, which is then suitably shaped from a flat metal strip into the U-shaped piston brace in a stamping tool. The use of a two-piece design has the advantage that the two component parts of different basic shapes can be manufactured separately according to their shapes instead of having to be formed from a single piece in a much more complicated way. Thus, piston brace 5 can also be advantageously made from a steel material, which provides significantly greater resistance to the forces occurring during operation. Piston brace 5 has a cylindrical opening 9 at its side opposite the piston body 3; center axis 11 of said cylindrical opening coinciding with center axis 13 of cylindrical piston body 3. On the inner side of the piston brace 5, opening 9 leads into a spherical cap-shaped region 15, which serves to receive a spherical cap-shaped piston shoe (not shown here). Likewise, at the side of brace 5 next to cylindrical piston shaft 3, a spherical cap-shaped region 17 which is capable of receiving a second piston shoe is provided within the brace; the two piston shoes sliding on a tilting plate or tilting ring located therebetween. The portion of brace 5 next to piston body 3 is provided with a smaller opening 19 which provides a connection to the interior of piston body 3. Piston body 3 is provided at its front end with two grooves 21 which serve to receive piston sealing rings.

[0039] In Figure 2, piston 1 of Figure 1 is shown in a side view in which it can be seen that piston brace 5 is provided on its upper side with a beveled step 23 leading to a raised region 25 with which piston 1 bears against a corresponding sliding surface of the housing inside the housing. Moreover, piston body 3 has two bevels 29 and 27 leading to a region 31 which has a larger diameter and acts as a guiding cylinder section within a cylinder liner. Within piston brace 5, axis 13 of cylindrical piston body 3 crosses an axis 33, the crossing point defining the center of a spherical shape of the spherical cap-shaped piston shoes and of bearing regions 15 and 17, respectively.

[0040] In Figure 3, piston 1 of Figure 1 and Figure 2 is depicted in a perspective view showing regions 35 in which a suitable coating can be applied to the steel components by

means of an adhesive base coat, especially by phosphating the entire piston in a layer thickness of about 2-3 μm , and by subsequently providing marked regions 35 with an anti-friction coating of PTFE in a layer thickness of about 10 μm . However, other coatings, such as WC/C coatings, or heat treatments, such as case hardening, are conceivable as well. The two-piece piston design is especially preferred because the different component shapes can be produced using manufacturing processes that are optimally adapted to the shapes. As has been mentioned earlier, deep-drawing of thin sheet steel is a suitable method for cylindrical piston body 3, while initial punching of sheet steel and subsequent bending to shape is convenient for piston brace 5. During the punching process, it is also possible to produce openings 9 and 19 and to preform spherical cap regions 15 and 17 in advance. In some cases, however, it may also be appropriate to select aluminum materials.

[0041] Figure 4 is a cross-sectional view of a piston 40. In this representation, piston 40 is shown solid in cross-section and may be manufactured, for example, from an aluminum material. Piston 40 likewise has a cylindrical piston body 42 and a brace 44; the end of brace 44 opposite the piston body 42 being provided with an opening 46 which corresponds to opening 9 of Figure 1. Opening 46 allows a cutting tool 48 to be inserted into the interior of piston brace 44. Thus, by rotation 52 about piston-cylinder axis 50, which corresponds to cylinder axis 13 in Figure 1, rear spherical cap 54 can be produced by the machining motion on standard lathes, which is not possible in the case of known forms of braces without such an opening 46. Moreover, in this machining process, a centering center 56 or a weight-reduction hole (not shown) can be made in piston body 42, and a second centering center 58 can be produced on the front face of piston body 42, these openings allowing dimensionally stable chucking during further processing steps on lathes and grinding machines, for example, for turning and grinding a coating.

[0042] Figure 5, finally, shows the machining of the front spherical cap shape 62 in brace 44. A cutting tool 60 for machining the front spherical cap shape 62 is also inserted through opening 46 in brace 44, and the spherical cap shape is then produced by suitably moving tool 60 axially and vertically during simultaneous rotation 52 of piston 40 about axis 50. This means that the piston brace has been altered by opening 46 in piston brace 44 in such a manner that the cutting motion for machining the spherical shape can be produced by rotating piston 40 about axis 50 of piston body 42, that is, about the cylinder axis. Therefore, neither special machines nor special devices are needed; the machining is not carried out under

interrupted cutting conditions, that is, the cutting tool does not move out of and back into the workpiece during machining and, in addition, it is possible to provide the edges of the spherical shape with lubricating wedge chamfers.

[0043] This results in both considerable cost savings and better quality of manufacture and in operational advantages for a machine having such pistons. Of course, the present invention is not limited in its use to air-conditioner compressors, but may also be used in other axial piston machines, such as axial piston pumps, that use diverse tilting-ring or tilting-plate mechanisms including piston shoes. Moreover, the present invention allows the coating of the piston to be processed on lathes and grinding machines in a very stable chucking position. Therefore, this type of chucking is considerably stiffer and more accurate compared to chucking in a centering center on the left side of the brace. As processing variants to the representations in Figures 4 and 5, it is also possible to use reversible inserts having a ready-made spherical contour. With these reversible inserts in a tool holder, it is also possible to machine both sides simultaneously.

[0044] Figure 6 is a top view of a piston 1 according to the present invention. Here, the reference numerals used correspond to those in Figures 1 and 2 again. In the top view of Figure 6, it can be seen, in particular, that bevel 23, which is shown in a side view in Figure 2, leads to a raised region 25 on piston brace 5, said raised region serving as a suitable contact and sliding surface with respect to the compressor housing wall. This sliding surface 25 exists both on the right and on the left side, that is, here, both at the top and bottom of Figure 6, and serves both as a sliding surface and to prevent the piston from rotating or tilting sideways.

[0045] Figure 7 is a perspective view of a piston 1 having a brace 5 and a first spherical recess 80 in the of brace 5. The components described hereinbefore are provided with the same reference numerals as, for example, in Figure 1, and will not be described again in order to avoid repetitions. Additionally shown here is first spherical recess 80, which can be produced simultaneously with the bearing surfaces 62 and, not visible here, 54 for the piston shoes during machining by rotation about cylinder axis 50.

[0046] Figure 8 shows the pressures and forces acting on piston 1 and piston brace 44, 5 during the suction stroke. During the suction stroke of the piston, tilting ring 82 or the tilting plate pulls piston 1 out of the cylinder block by means of the piston shoes (not shown here).

In this process, the movement of tilting ring 82 results in forces PA acting within piston brace 44, 5, said forces PA being transferred to brace 44 or 5 by tilting ring 82 and the piston shoe and tending to bend the brace 44, 5 open. In addition, inside the drive chamber, drive chamber pressure PC acts on the piston cylinder surface in region 62 of piston brace 44, 5, said drive chamber pressure acting against suction pressure PS on the front face of cylindrical piston body 42 or 3, respectively. Thus, during operation, brace 44 or 5 of piston 1 is primarily loaded by bending during the suction movement. In order to achieve maximum possible stiffness during this bending, the back of the brace is shifted radially inward as close as possible to tilting ring 82 or to the tilting plate, respectively; so that, in comparison with a brace that projects radially further outward, recess 80 is located so close to the bending line of the brace that the stiffness against bending during the suction movement is only slightly reduced compared to a brace that does not have a spherical recess 80 and which is located radially further outward and therefore has longer lever arms for bending. To this end, the back of brace 44 or 5, respectively, is adapted, on its inner side, to the cylindrical contour of the tilting ring or tilting plate and their moving positions by a second spherical recess 81, which can be seen in Figure 9. This results in a space-saving geometry, thus reducing the cost of the compressor.

[0047] In Figure 9, spherical recesses 80 and 81 in the piston brace are shown in four views. Figure 9a is a view of the inner side of the brace 44 or 5, respectively, showing the first spherical cap-shaped depression, that is, spherical recess 80, in the bridge of brace 44, 5 and a second spherical contour 81, which can occupy the entire inner side of the brace. Figure 9b shows section B-B of Figure 9a. Front bearing surface 62 for the front piston shoe can be seen within the cut brace 44 or 5. In cut region 88 of the piston ring, both the raised sliding regions 25 of Figure 6, which serve as a contact surface with housing contour 86, and first spherical recess 80 can be seen. It can also be clearly seen that second spherical recess 81 provides sufficient clearance from tilting ring contour 84 and the envelope generated by its pivotal movement, and that section B-B follows the contour of tilting ring 84 and housing 86.

[0048] Figure 9c shows that bearing surface 62 and/or opposite bearing surface 54 can seamlessly merge into first spherical recess 80 and form a spherical shape. Similarly to Figure 9b, the section shows second spherical recess 81, which is of considerably larger diameter than first spherical recess 80, and thus is adapted to the radius of the envelope of the tilting plate or of tilting ring 84 of Figure 9b.

[0049] In Figure 9d, spherical recess 81 of the inner surface of the brace can be seen particularly well from the side because of the perspective view. It also becomes clear that by producing bearing surface 62 for the piston shoe, the first spherical recess is simultaneously produced as well.

[0050] Figure 10 illustrates the production of first spherical recess 80 together with the production of piston shoe bearing surfaces 62 and 54. While a tool is rotated about an axis of rotation 90 within brace 44, the piston is rotated about its cylinder axis 50 to produce the spherical shape in the brace; the cutting edge of tool 92 producing the contours of bearing surfaces 62 and 54 for the piston shoes as well as spherical recess 80. Thus, by, as it were, shifting the brace 44, 5 closer to the outer contour of the tilting plate or tilting ring, spherical recess 80 is formed in the portion of brace 44 parallel to the cylinder axis during the machining of the spherical shape in brace 44 when using a rotation of piston 1 about its cylinder axis 50. This allows a cost-effective manufacturing process to be combined with a cost- and space-saving geometry of brace 44.

[0051] Spherical recess 80 is also formed when rotating the piston about an axis extending perpendicular between tool rotation axis 90 and cylinder axis 50 and running through their intersection point (center of the sphere), while a non-rotating tool cuts the spherical or nearly spherical contour.

[0052] Figure 11 shows a piston 101 having a cylindrical part 102 which is capable of reciprocating in the opening of a cylinder block 103 and whose cylindrical outer surface therefore forms the first sliding surface with respect to cylinder block bore 113. Piston 101 merges into a second part 104, which serves as brace for tilting plate 106 and piston shoes 105. When tilting plate 106 rotates, piston 101 is caused to reciprocate by means of piston shoes 105, during which tilting plate 106 slides between the flat sides of piston shoes 105, while the piston shoes 105 themselves perform a kind of a wobbling motion within the piston brace. Piston brace 104, in turn, slides in drive mechanism housing 107, which is only partially shown, along inner wall 108, thus forming a second sliding surface 109.

[0053] Figure 12 is a cross-sectional view through the piston brace, such as is described in the present invention and shown in a top view in Figure 13. In Figure 13, second sliding

surface 109 is pierced by an opening 111 via which lubricant from the interior, especially that thrown off of rotating tilting plate 106 (Figure 11) by centrifugal forces, is conveyed through the piston brace to the upper side, that is, to sliding surface 109. A sliding surface 115 for the front piston shoe can be seen on piston brace front surface 114 below the cut piston brace surface 112; a piston shoe 105 of Figure 11 performing a wobbling motion in said sliding surface. Opening 111 can be frustoconical in shape so as to catch the lubricant over a wider area.

[0054] Figure 13 is a top view of a piston according to the present invention. Cylindrical piston part 101, the diameter of which is smaller than that of the curvature of brace surface 109, is adjoined by the second portion, piston brace 104. Located in brace part 104 is the opening 111 provided for lubricant supply, which here is, for example, oval in cross-section, and is surrounded by a pocket-shaped recess 116 for receiving the lubricant. This pocket-shaped opening 116 is shown in cross-section in Figure 16. Also indicated in Figure 13 is an adjacent piston brace 104', which shows that, in a machine according to the present invention, there is only a very small gap 117 left between the piston braces, which may not be sufficient for lubricant supply to brace sliding surfaces 109.

[0055] Figure 14 shows, by way of example, six piston braces in cross-section in one machine. It can be seen that there are only very narrow gaps 117 between the six piston braces 104 with their sliding surfaces 109. This means that lubricant that is spun off of a rotating slant or tilting plate within the drive chamber may possibly not be able to make its way from gaps 117 to the center of sliding surfaces 109.

[0056] Therefore, in accordance with the present invention, and as shown in Fig. 15, lubricant supply is provided through opening 111 in that lubricant 118 is passed, under the action of the centrifugal forces, from the rotating slant or tilting plate or tilting ring 106 through the opening to surface 109, where it can lubricate second sliding surface 109 between the drive chamber housing wall and the radial outer surface of piston brace 104.

[0057] Figure 16 also shows a cross-section of a piston brace 104 according to the present invention; the surface 109 of said piston brace being provided with a lubricant pocket 116 in addition to lubricant opening 111; it being possible for the lubricant pocket to be made in different shapes, as required. The purpose of this lubricant pocket is to collect the lubricant

that has passed through opening 111 above the piston brace, and to supply it to sliding surface 109 in sufficient quantities.